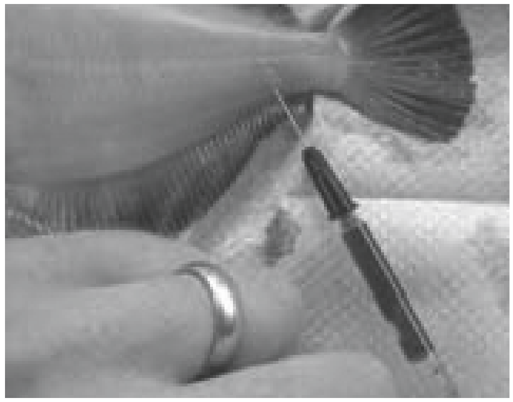
Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds

Several groups of organic compounds have been found in trace amounts in surface waters and fish tissue due to improved analytical and biomarker detection capabilities. These trace organic compounds (TOrCs) include pharmaceuticals, personal care products, surfactants, pesticides, flame retardants, and other organic chemicals, some with unknown modes of action or effects. Identifying or predicting ecological effects of TOrCs in typical aquatic multi-stressor situations is challenging. It often requires a variety of epidemiological tools that together, can diagnose effects at multiple scales of ecological organization.



This research provides information on trace organic compounds to help inform scientifically defensible and cost effective decisions.

The objective of WERF's TOrCs Knowledge Area research is to provide essential frameworks, tools, and information to wastewater treatment managers, to ensure that they are making scientifically sound and appropriate treatment decisions to guarantee healthy aquatic ecosystems in receiving waters. The goal of this particular WERF project, *Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds*, was to provide information on TOrCs to help the water quality community make scientifically defensible and cost effective decisions that are appropriately protective of aquatic populations and communities.

Five objectives were addressed in this research:

1) Develop and apply a procedure to prioritize which TOrCs are of most concern.
2) Develop and test a conceptual diagnostic framework to identify TOrC by source type.
3) Develop exposure-response models for high priority TOrCs.
4) Develop and populate a relational database of TOrC exposure and effects data.
5) Foster partnerships and transfer knowledge gained to the water quality community.

The final report summarizes approaches used and results obtained. It discusses critical data gaps and other uncertainties, and provides testable hypotheses and recommendations for Phase 2 testing and analyses. There are companion pieces to this research. They include a TOrC prioritization framework, a report on diagnostic approaches and types of analyses used to identify causes of ecological impairments in aquatic systems, seven case studies, and a web-based database (traceorganicsecotool.werf.org) to help users search and evaluate TOrC data.

Which TOrCs Should I Monitor? A Framework for Prioritizing

The development of screening and diagnostic tools presented in this report could benefit end users by helping them prioritize which sites most require monitoring and assessment of TOrCs and whether TOrCs are a factor of concern at their site.

BENEFITS

- Provides prioritization approaches for identifying TOrCs that should be monitored or considered at a given location.
- Provides an approach to calculate estrogenicity equivalents of various TOrCs for prioritization and diagnostic assessments.
- Identifies screening indicators to help prioritize sites with respect to ecological risks due to TOrC.
- Provides a conceptual approach for diagnosing aquatic ecological effects due to TOrCs.

RELATED PRODUCTS

Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds: Prioritization Framework for Trace Organic Compounds (CEC5R08a)

Development of Diagnostic Tools for Trace Organic Compounds and Multiple Stressors (CEC5R08b)

Testing Diagnostic Tools for Trace Organic Compounds and Multiple Stressors: Case Studies (CEC5R08c)

WERF Trace Organics Ecological Database (traceorganicsecotool.werf.org)

Workshop Proceedings: Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds on Aquatic Populations and Communities (CEC5R08W)

RELATED ONGOING RESEARCH

Categorizing Wastewater Treatment Processes by Their Efficacy in Reduction of a Suite of Indicator TOrC (CEC4R08)

AVAILABLE FORMAT

Soft cover and online PDF.

TO ORDER

Contact WERF at 571-384-2100 or visit www.werf.org and click on Search Research Publications & Tools.

WERF Subscribers: Your first hardcopy of this report is free. Additional copies are $10 each or download unlimited free PDFs at www.werf.org.

Non-Subscribers: Charges apply to some products. Visit www.werf.org for more information.

Refer to: **STOCK NO. CEC5R08**

For more information, log on to **www.werf.org**.

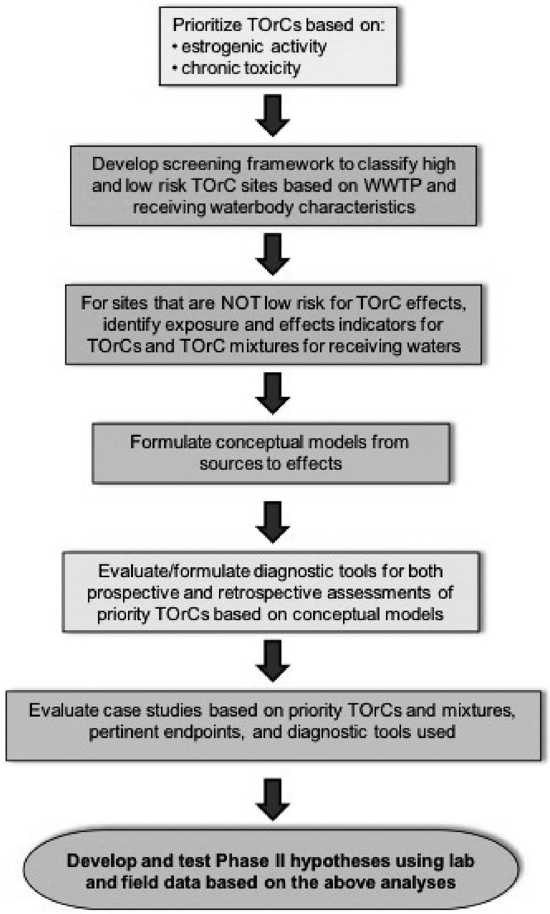


Figure 1. Flowchart Summarizing the Approach Used in Phase 1 of the Research Regarding Ecological Effects of Trace Organic Compounds.

Figure 1 shows the general conceptualization of this research and the context of screening and diagnostic tools discussed by the investigators.

Sites (e.g., a waterbody receiving treated effluent) should first be screened to determine whether they are low risk, high risk, or the risk is unknown for TOrC effects. If it can be demonstrated that a given site is low risk for TOrC effects, further monitoring and assessment of TOrCs is probably not warranted. If the site could have a high risk (or unknown risk) due to TOrCs, monitoring may be warranted. In this case effluent or receiving waters could be screened using the priority TOrC lists developed to determine if high risk chemicals are present.

Researchers developed three types of approaches for prioritizing TOrCs that may be high risk and that might be considered for monitoring.

- **Risk-based:** Max concentration divided by most sensitive predicted effects threshold (toxicity or estrogenicity). Quotient $\geq$ 0.10 considered high priority.
- **Risk-based and fate-based:** Sum of effect, bioaccumulation, and persistence scores; effect score based on quotient as in Approach #1; quotient $\geq$ 0.10 = score of 3 (highest priority); log $K_{ow} \geq 5.0$ = score of 3; half-life in water $\geq$ 180 d = score of 3. Total score $\geq$ 7 is high priority TOrC.
- **Tox and fate-based:** Sum of toxicity, bioaccumulation, and persistence scores; toxicity score based on predicted chronic toxicity; bioaccumulation and persistence scores same as in Approach #2.

Each approach has its advantages and limitations as described in the report (See page 2-5 of CEC5R08 and Chapter 4.0 of CEC5R08a) and is summarized below.

TOrCs identified as high priority differed among approaches: steroids, hormones, pharmaceuticals, and surfactants comprised most of the high priority TOrC based on a risk approach, while pesticides, industrial chemicals, and PAHs comprised most of the high priority TOrCs based on a persistent, bioaccumulative, and toxic chemical (PBT) approach.

The risk-based approach resulted in the fewest number of high priority TOrCs (41) while the PBT approach resulted in the greatest number of high priority TOrCs (108). A total of 23 TOrCs were identified as high priority using all three approaches and a total of 126 TOrCs were identified as high priority using any one of the approaches.

What Types of Wastewater-Influenced Sites Are at Most Risk Due to TOrCs?

The research team developed a framework and tools for use by the water quality community to screen sites for TOrC risks to aquatic biota. If a site could have a high risk (or unknown risk) due to TOrC, monitoring may be needed. The TOrC listed as high priority in Table 2-3 on page 2-6 of the report could serve as a guide to what type of TOrC to monitor. The framework could be used both prospectively and retrospectively depending on the end-user's objective.

The screening approach developed in this research focuses on wastewater discharge sources and is a first step toward developing an effective screening tool.

Figure 2 and Table 1 present hypothesized risk factors used in the screening process and characteristics are grouped as:

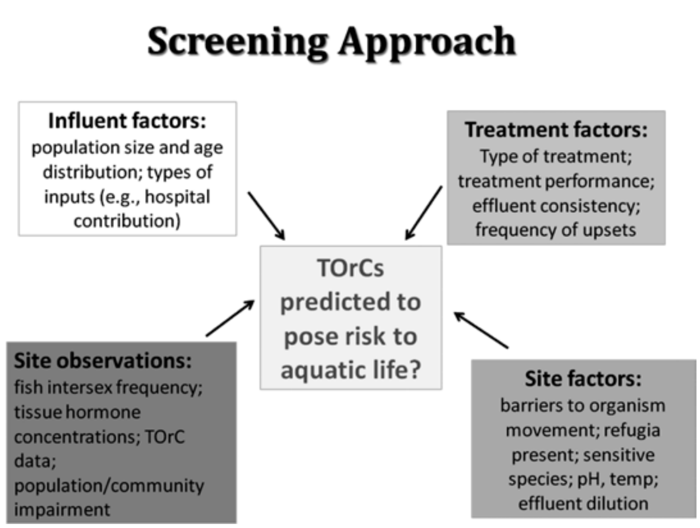


Figure 2. General Schematic Showing Hypothesized Factors Considered in Screening Wastewater Sites for Diagnostic Analyses Involving TOrCs.

Table 1. Draft Criteria for Screening Waste Water Treatment Plant Effluent-Influenced Sites for Potential Aquatic Ecological Effects Due to Trace Organic Chemicals.

	Risk Thresholds		
	Factor	Lower Risk	Higher Risk
WWTP Input Characteristics	Industry/hospital-related influents	None or very minor	>5% of influent
	Population served	< 10,000	> 1M
	Average age of population	< 30	> 50
WWTP Treatment Characteristics	Level of treatment	Tertiary, advanced secondary	Secondary or Primary
	Sludge retention time (SRT)	> 15d	< 5d
	Treatment effectiveness/uniformity	Low (near reference condition) nutrient concentrations; TSS	High (relative to reference conditions) nutrient levels; TSS
	WWTP upsets	None	Several
	Uniformity of influent flow and water quality	Relatively uniform most of the time	Very inconsistent in terms of flow and/or quality
Receiving Waterbody	Percent Effluent Instream (low flow)	< 1%	> 70%
	Waterbody size and/or habitat diversity	Large (e.g., > 5th order) waterbody; abundant refuges	Small waterbody; refuges few or non-existent
	Waterbody openness/barriers	No barriers to fish movement	Dams or other barriers preventing fish movement
	Threatened, endangered, or species of concern present	None	At least 1
	Presence of other potential sources of TOrCs	None	Agricultural (CAFOs, row crops, orchards) sources present upstream or nearby urban stormwater?
Site Observations	Existing EDC effects present	None	Significantly higher vtg induction in male fish; abnormal frequency of intersex in fish
	TOrC concentration > screening threshold level (from literature values)	No	Yes

1) wastewater influent characteristics, 2) wastewater treatment characteristics, 3) receiving system characteristics, and 4) site ecological and TOrC concentration data (measured or predicted). Using the guidance from information gathered for Table 1, one can further categorize sites to determine if a specific site warrants further investigation for TOrC impairments. Sites are likely to range from low risk to high risk and can be categorized as shown in Table 1.

Diagnosing Potential or Actual Ecological Effects Due to TOrCs

A demonstration application of the screening approach was conducted in a retrospective assessment of available data from wastewater-influenced sites in the Drift Plain ecoregion of Ohio (See Chapter 4.0 of CEC5R08 report or Case Study report, CEC5R08c). Sites of particular interest for TOrC risk had high risk criteria for both the associated wastewater treatment facility and receiving water characteristics; had predicted TOrC exposure (household chemicals and/or pharmaceuticals) identified as a potential stressor by quantitative analysis; and were either simple (TOrCs were the only predicted stressor) or complex (multiple stressors) risk scenarios (Table 2). This categorization of risk scenarios was used in several other case studies examined in this research.

Two sites in Ohio that were screened as high risk for TOrCs and five other sites from different geographic locations were examined further to demonstrate the use of different diagnostic tools and to identify critical gaps in terms of diagnosing risks due to TOrCs. The use of these various lines of evidence in this screening assessment effectively used readily available data to screen high priority sites before devoting more resources in assessment and diagnostics at the site level.

One of the critical challenges in diagnosing risks due to TOrCs is that at higher levels of organization (population, community), there may not be “diagnostic” impacts that are attributable only to specific TOrCs (or classes of TOrCs). A decline in fish growth

Table 2. TOrC Risk Scenario Categories Used in Screening Sites.

TOrC RISK

Site Risk Classification	WWTP Facility	Receiving Waterbody
LEVEL I (Lowest)	Low risk	Low risk
LEVEL II	Low risk	High risk
LEVEL III	High risk	Low risk
LEVEL IV (Highest)	High risk	High risk

rate, for example, could be due to a decline in availability of food resources, as much as to impaired physiology associated with chronic TOrC exposure. Therefore, the diagnostic approach must use multiple lines of evidence and look for patterns of responses that are not attributable to other stressors.

WERF TOrC Database

The research team compiled TOrC fate, effects, and occurrence data in a database for over 500 organic chemicals based on over 100 published studies representing more than 50 organizations and 700 sites. A web-based relational database was developed (traceorganicsecotool.werf.org) using an easy-to-use Microsoft platform which the water resource community could store, query, and search TOrC data, as well as biological and aquatic life habitat information for sites in the U.S. This could be a useful tool for the water quality community to help track and analyze spatial and temporal trends in TOrC and associated ecological information at various locations.

Where Do We Go From Here?

While uncertainties and data gaps still exist, the investigators advise that those utilities and other organizations managing water resources do not need to wait for Phase 2 to be completed in order to obtain useful information for assessing and managing TOrC. The site screening tool developed in this research, while simple, is a useful first step to decide whether TOrC are a potential cause for concern at a site. The prioritization approaches developed are a useful starting point for deciding which TOrC should be monitored in the receiving waterbody or effluent. Partitioning the ecological effects of trace level organic compounds on aquatic populations and communities will be a long-term process. Nevertheless, the Phase 1 research has provided tools for gathering information relating to population and community effects of TOrC and laid a solid foundation for the Phase 2 and future research.

Recommendations regarding future monitoring and assessment activities that should be considered in Phase 2 of this project are discussed in full detail in Chapter 6.0 of the report.

CONTRACTOR

Jerry Diamond, Ph.D.
Center for Ecological Sciences, Tetra Tech, Inc.

RESEARCH TEAM

Steve Bartell, Ph.D.
E2 Consulting Engineers, Inc.

Katherine Kapo, Ph.D.
Montani Run LLC

Karen Kidd, Ph.D.
Kelly Munkittrick, Ph.D.
University of New Brunswick

Kent Thornton, Ph.D.
FTN Associates, Inc.

Jennifer Flippin
Herb Brass, Ph.D.
Henry Latimer
Jaime Gilliam
Jeroen Gerritsen, Ph.D.
Jeffrey White
Center for Ecological Sciences, Tetra Tech, Inc.

TECHNICAL REVIEWERS

Steve Bay, Ph.D.
Southern California Coastal Water Research Project

Mary Buzby, Ph.D.
Merck & Co.

Bill Cairns, Ph.D.
Trojan Technologies

Paul DeLeo, Ph.D.
American Cleaning Institute

Scott Dyer, Ph.D.
The Procter and Gamble Company

Erich Emery
Ohio River Sanitation Commission

Mike Focazio, Ph.D.
U.S. Geological Survey

Deb Lester
King County Department of Natural Resources

Drew McAvoy, Ph.D.
University of Cincinnati

Jim Pletl, Ph.D.
Hampton Roads Sanitation District

Margaret Nellor, P.E.
Nellor Environmental Associates

Elizabeth Toot-Levy
Northeast Ohio Regional Sewer District

6/11